

# **Assessment of STEM Integrated Learning**

A teacher workshop

# **This workshop will discuss....**

The Six 'W's of Assessment in STEM:-

- 1. Why?**
- 2. What?**
- 3. Where?**
- 4. When?**
- 5. How?**
- 6. Who?**

# STEM education:

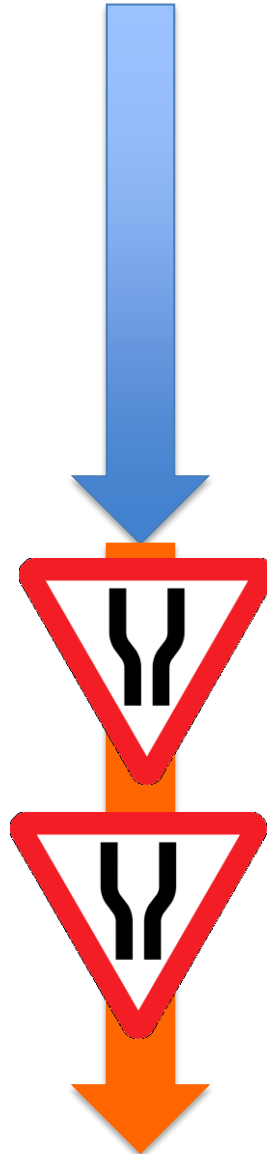
## What have been discussed and what not

**Theory/Macro**

- Vision and goals (STEM literacy, 21<sup>st</sup> century skills)
- Content areas (Robotics, Smart City, 3-D printing, AI)
- Learning approaches (interdisciplinary, inquiry-based, design-based, problem-based, project-based)

**Practice/Micro**

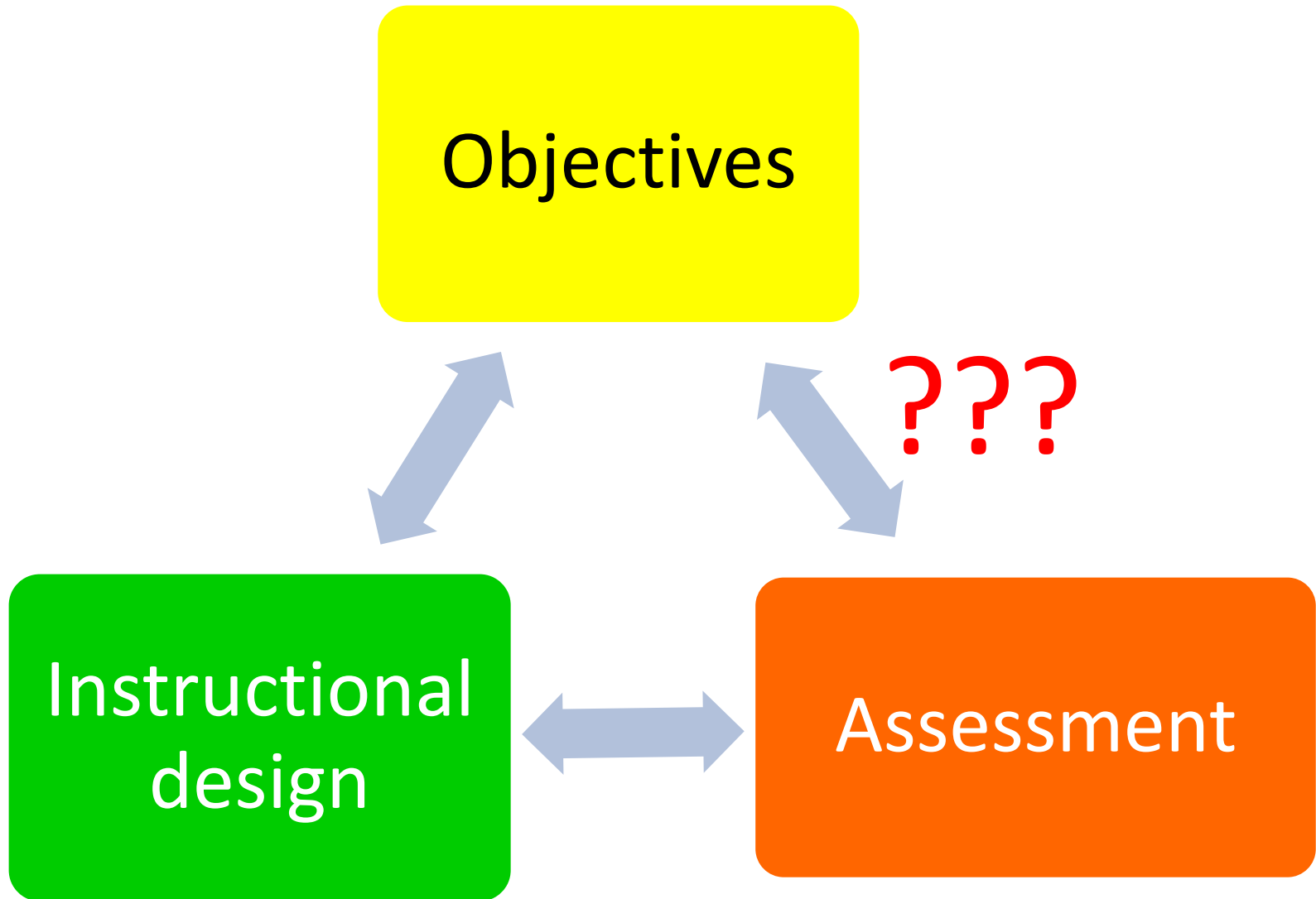
- Curriculum organization and interdisciplinary collaboration
- Curriculum design (incl. SDL and assessment)



# **Assessment in STEM:**

## **1. The 'Why'?**

# The curriculum process



# Can the existing assessment measures cater to assessment in STEM?

- Context? Authenticity?
- Range of outcomes assessed?
- Low-order thinking or high-order thinking?
- Compartmentalized or Integrated?
- Knowledge or skills?
- Summative or formative?

# Assessment - a bottle-neck in STEM education

**THREE** problems to address:

1. What are the intended learning outcomes (ILOs) to be assessed? (A curriculum problem)
2. How to develop valid assessment measures? (A professional problem)
3. How to integrate STEM assessment into the current school assessment and reporting system? (A political problem)

## 2. The 'What'?

What to assess in integrated  
STEM



Specifying intended learning  
outcomes (ILOs)

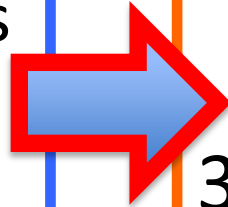
## \*Activity\*

- Devise 5 ILOs that you think are most important for integrated STEM education.

# Intended learning outcomes of Integrated STEM education

## Emphases of STEM education

1. Integration of knowledge and skills across disciplines (learning aspect)
2. Innovative problem solving (action aspect)



## Domains of ILOs

1. Cognitive domain
2. Metacognitive domain
3. 21<sup>st</sup> century skills
4. Attitudes

# 1. Cognitive Domain

## Revised Bloom's Taxonomy (Anderson, et al 2001)

E.g. Science	Factual	Conceptual	Procedural	Meta-cognitive
Remember	<b>State</b> the laws of levers			
Understand		<b>Understand</b> <u>how levers provide leverage</u>		
Apply			<b>Apply</b> the <u>law of the lever in calculating the effort needed to raise a load</u>	
Analyze		<b>Analyze</b> <u>the data from an experiment to deduce the law of the lever</u>		
Evaluate		<b>Evaluate</b> <u>the sufficiency of the data to reach the conclusion</u>		
Create		<b>Plan</b> for <u>an investigation into the law of the lever</u>		

Science	Factual	Conceptual	Procedural	Meta-cognitive
Remember				
Understand				
Apply				
Analyze				

S

+

Technology	Factual	Conceptual	Procedural	Meta-cognitive
Remember				
Understand				
Apply				
Analyze				

T

?

Engineering	Factual	Conceptual	Procedural	Meta-cognitive
Remember				
Understand				
Apply				
Analyze				
Evaluate				
Create				

E

Mathematics	Factual	Conceptual	Procedural	Meta-cognitive
Remember				
Understand				
Apply				
Analyze				
Evaluate				
Create				

M

# Emphases of integrated STEM education

## (1) High-order thinking

	Factual	Conceptual	Procedural	Metacognitive
Remember				
Understand				
Apply				
Analyze				
Evaluate				
Create				

Higher-order thinking

# Emphasis of integrated STEM education

## (2) Hands-on, minds-on

	Factual	Conceptual	Procedural	Metacognitive
Remember				
Understand				
Apply			Hands-on, minds-on	
Analyze				
Evaluate				
Create				

# Emphasis of integrated STEM education

## (3) Self-directed learning & PBL

	Factual	Conceptual	Procedural	Metacognitive
Remember				
Understand				
Apply				
Analyze				
Evaluate				
Create				

Self-directed learning & Problem-based learning



## 2. Metacognitive Domain

### (後設認知知識)

1. Understanding strategies for learning, thinking and problem solving
2. Understanding strategies for performing different cognitive tasks
3. Awareness of one's strengths, weaknesses and abilities in applying those strategies

*\*\* Metacognitive knowledge is the basis of self-directed learning.*

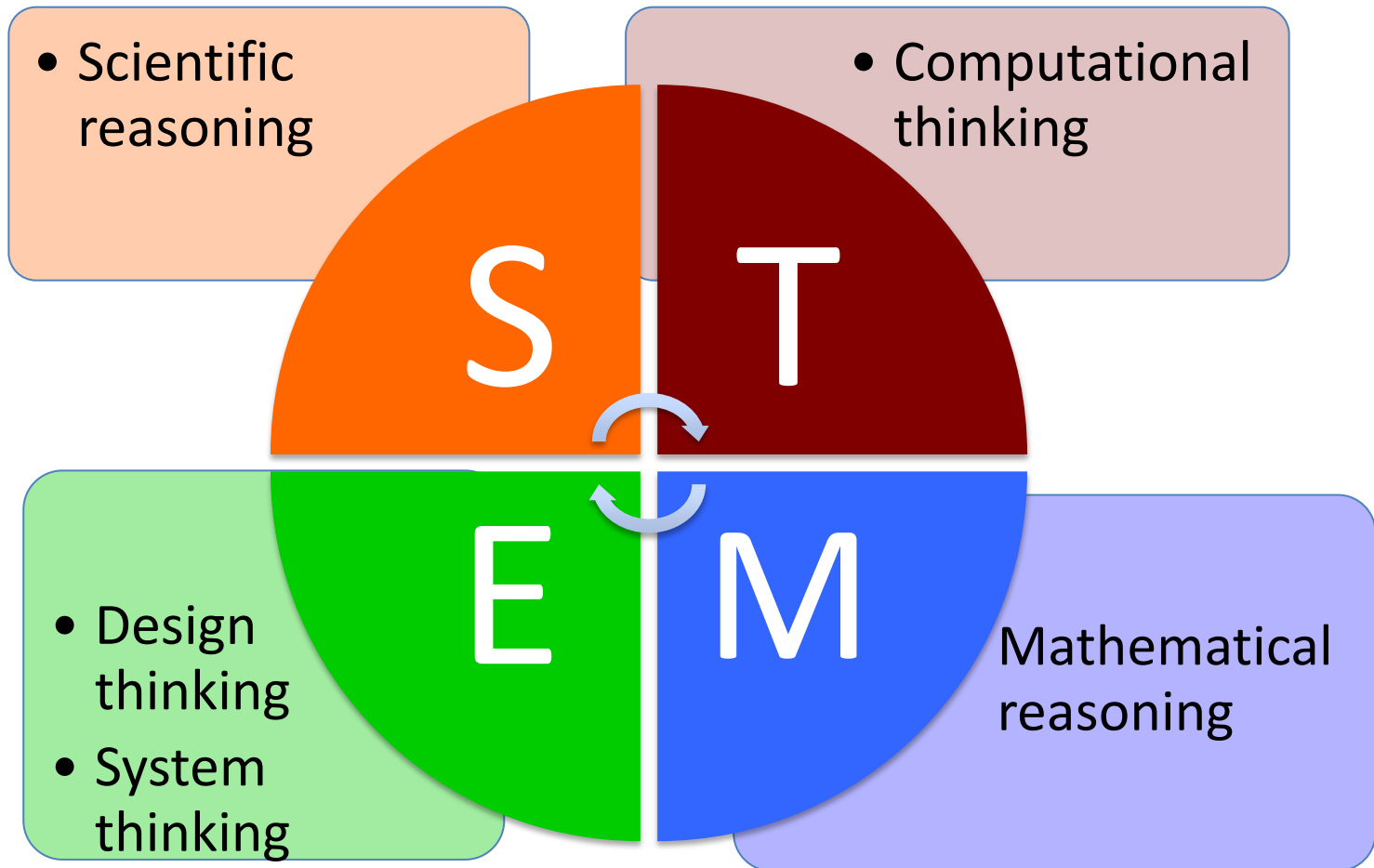
# Emphasis of integrated STEM education

## (4) Integration of knowledge

	Factual	Conceptual	Procedural
Remember			
Understand			
Apply		<p><b><u>E (&amp; S, T, M)</u></b>: Applying science, mathematics and engineering concepts and processes to solving a problem</p>	<p><b><u>T (&amp; S, E)</u></b>: Using technology devices or processes (including ICT) to collect and analyze data, or to make artifacts</p>
Analyze		<p><b><u>S (&amp; M)</u></b>: Interpreting relationships from experimental data in mathematical terms</p>	
Evaluate		<p><b><u>E (&amp; S)</u></b>: Determining whether a solution could meet a certain set of criteria and constraints with due consideration to the sufficiency of data to support the conclusion</p>	
Create		<p><b><u>E (&amp; S, T, M)</u></b>: Designing and planning a solution to solve a problem by integrating multi-disciplinary knowledge</p>	

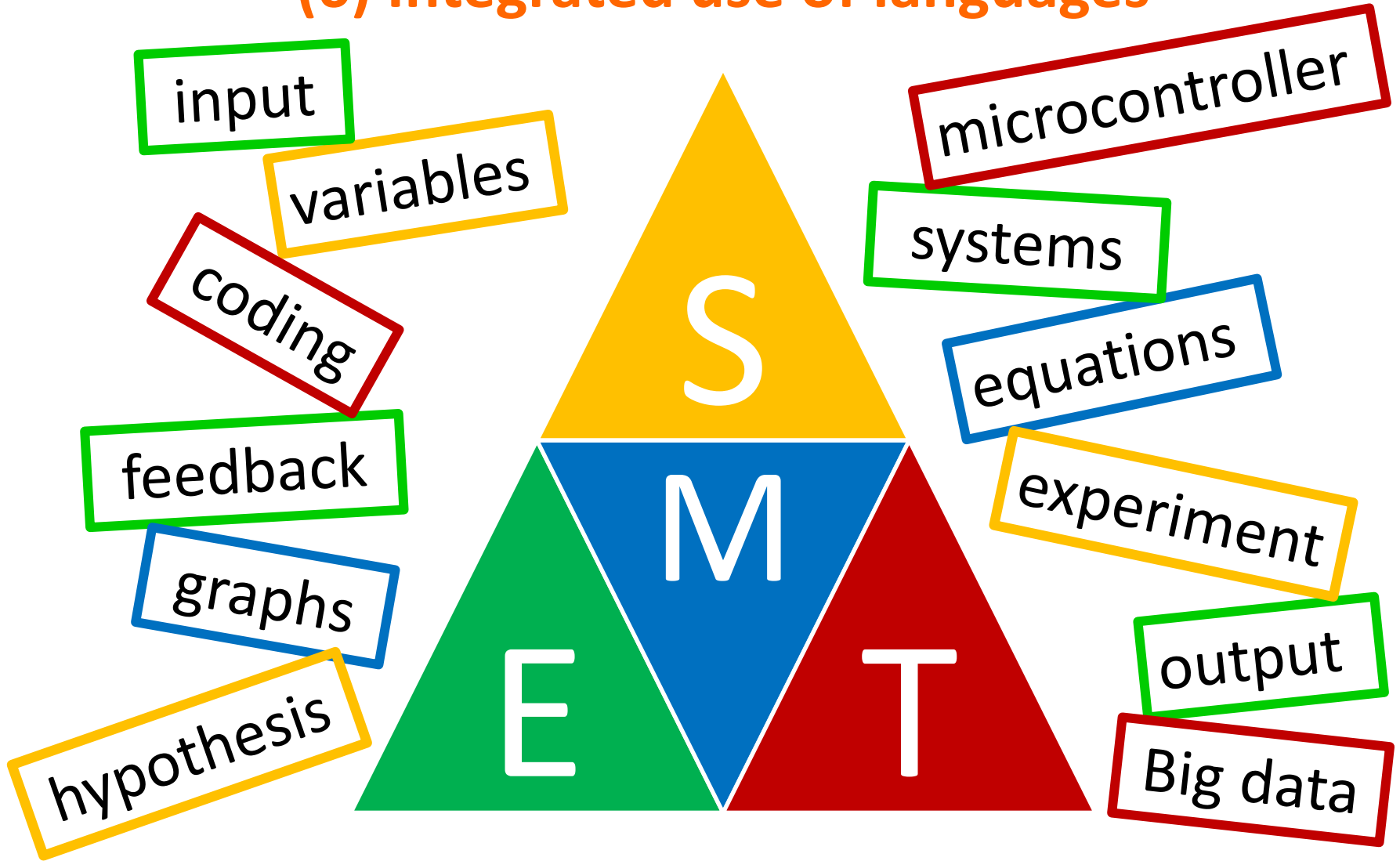
# Emphasis of integrated STEM education

## (5) Integration of reasoning



# Emphasis of integrated STEM education

## (6) Integrated use of languages



## 3. 21<sup>st</sup> century skills

- Communicating information, ideas, designs/solutions and arguments
- Critical reasoning and argumentation
- Collaborating with peers
- Problem solving
- Creativity and innovativeness
- Self-learning, self-monitoring, self-reflecting and self-regulating

# 4. Affective Domain

## Attitudes (related to disciplines)

- Objective, able to tolerate ambiguity or uncertainty, curiosity, honesty, striving for optimization, open-minded, willing to take risks, being precise and reflective

## Attitudes toward STEM

- Interest, willingness to participate, valuing, persevering, self-confidence, feeling satisfied

## \*Activity\*

- Add 5 more ILOs to your list to make a total of **10** STEM ILOs that you think are most important

# 3. The 'Where'?



# Sources of evidence

- Where could you obtain evidences of student achievement?

**\*Activity\***

- List as many *sources of evidence* as possible for assessing STEM learning outcomes

## 4. The 'When'?

# Formative or Summative?

During the learning process - Formative assessment

After the learning process - Summative assessment

## \*Activity\*

- What are the sources of evidence that are useful for:
  - formative purpose?
  - summative purpose?
- Re-arrange your sources of evidence in chronological order

\*Add additional sources to your list as you see fit

# Summing up

Purpose

Formative



Summative

Sources of evidence

Work plan

Research plan

Design drawing

Scientific investigation

Portfolio

Prototype

Testing record

Revised prototype

*Student reflection*

Artifact

Presentation

Competition

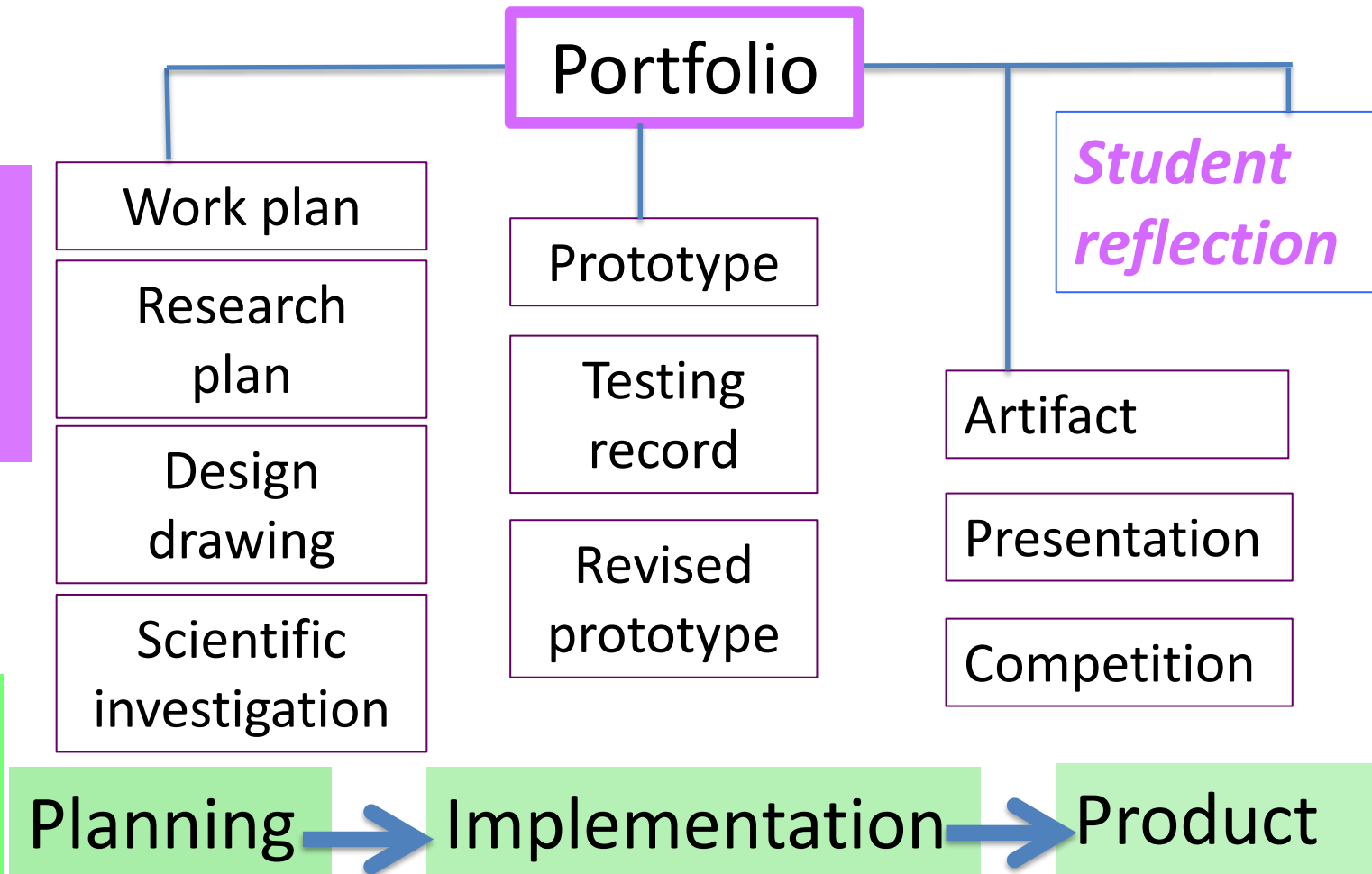
Stage of activity

Planning



Implementation

Product



**Next:**

*Matching ILOs with sources of evidence.*

# \*Activity A\*

## Assessing designs

Design a small container that can keep a can of coke ( $330 \text{ cm}^3$ ) cold after it was taken out from the fridge.

- Criteria for your design:
  - Only a gain of  $10^\circ\text{C}$  is allowed after half an hour.
  - The volume of the container is no more than double that of the coke can (Diameter = 7cm; Height = 12cm)
  - Reusable
- Constraint:
  - Can only use simple materials available in a stationery store or a supermarket

Draw your design in the form of an annotated diagram illustrating the scientific principles of your design, and the dimensions with calculation shown.

## **\*Discussion\***

1. What ILOs could be assessed based on the design drawing?

*(Check from your list of ILOs)*

2. What are the limitations of design drawing as evidence of learning?

# **\*Activity A\*** ILOs assessed (Suggestions)

1. Understanding and application of scientific concepts
2. Understanding and application of mathematical concepts and skills
3. Problem solving
4. Creativity
5. Skills for making design drawings
6. Written communication skills



## \*Activity B\*

### Assessing products/Artifacts

1. Examine the TWO problem scenarios and artifacts provided.
2. What ILOs could be assessed based on artifacts produced by students?  
*(Check from your list of ILOs)*
3. What are the limitations of artifact as evidence of learning?

# **\*Activity B\*** ILOs assessed (Suggestions)

1. Understanding and application of science/engineering conceptual knowledge (e.g., levers, feedback system)
2. Understanding and application of scientific/technological procedural knowledge (e.g., fair test, coding)
3. Problem solving
4. Hands-on/crafts/IT skills
5. Creativity

# \*Activity C\*

## Assessing process (Student portfolio as evidence)

1. Examine the TWO e-portfolios shown.
2. What do they tell you about student achievement?
3. What ILOs could be assessed based on student portfolios?

*(Check from your list of ILOs)*

1. What are the limitations of portfolios as evidence of learning?

# \*Activity C\* ILOs assessed (Suggestions)

1. Information search/research skills
2. Problem solving (planning)
  - Generating alternative solutions
  - Generating hypotheses (if investigations required)
  - Breaking down the tasks into sub-tasks and sequencing them appropriately
3. Problem solving (implementation)
  - Testing/experimentation
  - Trouble-shooting
  - optimization
4. Hands-on/crafts/IT skills (including use of tools/instruments)
5. Collaboration
6. Communication
7. Critical reasoning
8. Attitudes

## \*Activity D\*

In your table, match all your sources of evidence with your learning outcomes.

# \*Discussion\*

- Which source(s) of evidence are most widely applicable to measuring learning outcomes?
- Which source(s) of evidence are least widely applicable to measuring learning outcomes?
- Which source(s) of evidence are most useful for measuring cognitive outcomes?
- Which source(s) of evidence are most useful for measuring meta-cognitive outcomes?
- Which source(s) of evidence are most useful for measuring 21<sup>st</sup> century skills?
- Which source(s) of evidence are most useful for measuring attitudes?

# 5. The 'How'?

# Judging performance/achievement

1. Modes of assessment (= sources of evidence)
2. Assessment criteria (= ILOs)
3. Levels of achievement

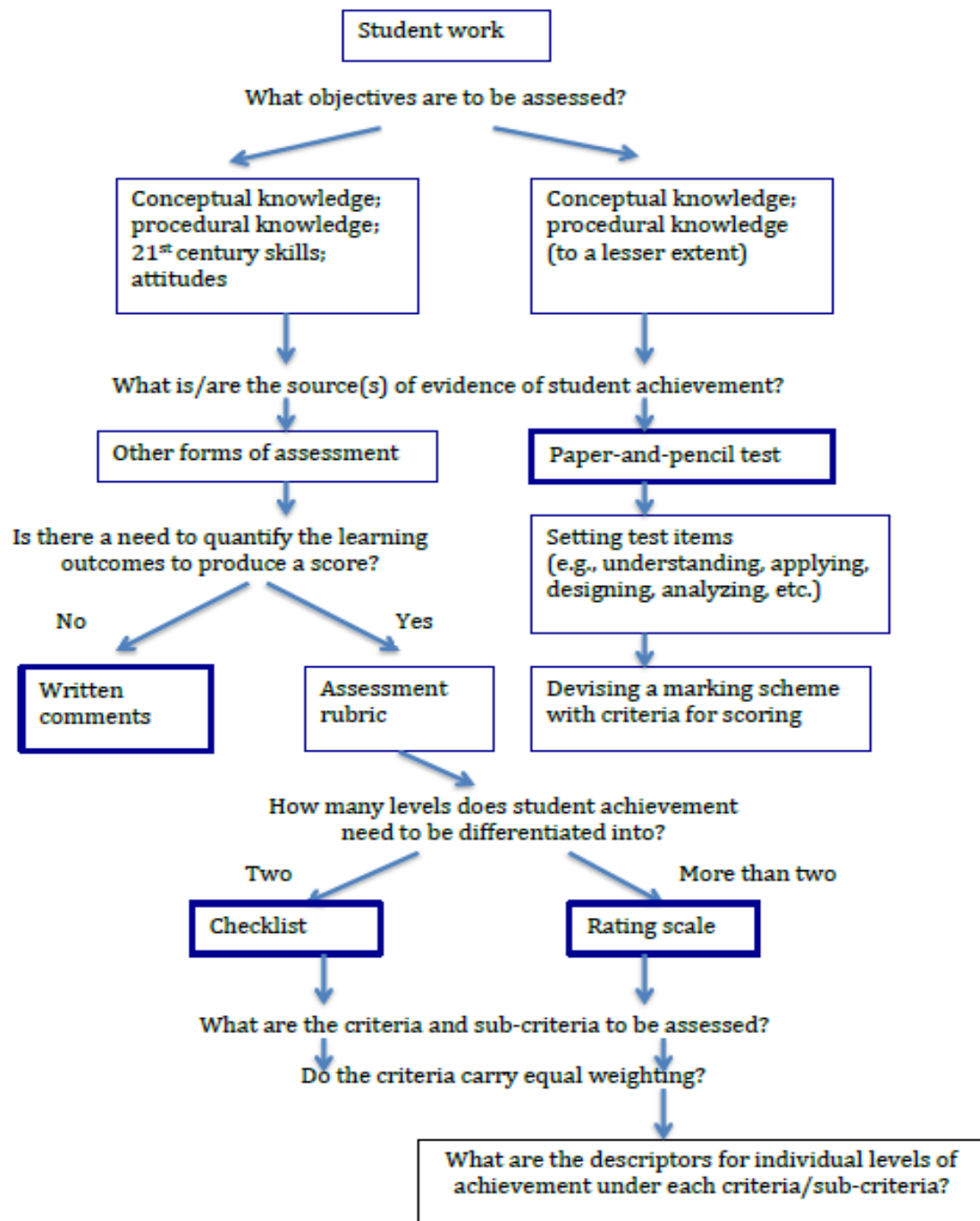
Purposes:-

- recording achievement
- differentiating abilities
- indicating progression
- Providing feedback



A road map for choosing and  
designing assessment measures

# A guide to designing assessment for STEM activities



# Designing assessment rubric

## *(Suggested steps)*

1. Deciding on the assessment criteria/ILOs
2. Defining the criteria operationally (**sub-criteria**)
3. Deciding on the number of levels of achievement (**for differentiation and progression**)
4. Naming the levels of achievement
5. Deciding whether descriptors for individual levels are needed
6. Setting descriptors

# E.g. Criterion: Problem-solving skills

<b>Sub-criteria</b>	<b>High</b>	<b>Middle</b>	<b>Low</b>
<b>Problem analysis</b>	Sequence the sub-tasks	Divide problem into sub-tasks	Take problem as a single task
<b>Considering alternative solutions</b>	Develop criteria for differentiating alternative solutions	Develop alternative solutions	Consider only a single solution as if there is a only a single answer to the problem.

# Hints for designing level descriptors

- Use 'absolute' descriptors (illustrated with evidences)
- Use relative descriptors (in case where absolute descriptors are not obtainable)
- Relate to frequency/occurrence of performance
- Relate to level of assistance rendered by others (teachers/parents)

# \*Activity\*

Pick one of the following ILOs and break it down into sub-criteria:-

1. Creativity
2. Collaboration with peer
3. Collecting information (Researching)
4. Students' self-reflection on learning

Set the levels and descriptors for one of your sub-criteria.

- Exchange your rubric with another group and talk about what they have produced.

# Scoring

\*Activity\*

Scoring your design drawing using an assessment rubric

- Swap your design (coke package) with another group and assess the design using the assessment rubric provided



# Reflection on scoring using assessment rubric

1. Is your assessment/scoring reliable and valid?
2. What are the limitations or potential risks in using assessment rubrics for scoring?
3. How to further improve assessment using rubric?

## 6. The 'Who'?

# Who could be the assessor?

1. Teacher
2. Self
3. Peer (within or outside the student group)
4. Others (e.g., parents, judges)

## \*Activity\*

- What ILOs can best be assessed through self and peer assessment?
- Modes of self/peer assessment (e.g. Google form on SDL)

# **\*Discussion\***

- What are the advantages and disadvantages of self and peer assessment?
- How to make full use of these two assessment measures?

# Paradigm shift in assessment

1. Assess a wider range of intended learning outcomes
2. Make assessment more meaningful and valid
3. Shift emphasis from summative to formative assessment
4. Move from singular to multiple assessment modes
5. Make assessment criteria and levels of performance more transparent
6. Put onto students the responsibility for learning and achieving
7. Focus on progression of attainment (**across ability levels, grades and key learning stages**)

# Final words about assessment

- Make as much evidence of your students' achievement

as 'accessible', and 'assessable' as possible.



# Reflection

- Please take a fresh look at your group's BIG assessment table.
- **What changes would you like to make to your table after this workshop?**



- No universally applicable assessment practice !
- Need to tailor to your own needs and your students' and school's needs !
- **This workshop is to present to you various possibilities to stimulate your thinking !**



# STEM Education

A golden opportunity to reform  
school assessment

OR

Another initiative to be stifled by  
the prevailing school assessment  
system

???



THANK



YOU

